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Federal Communications Commission
Office of Secretary

BY MESSENGER

Mr. William F. Caton
Acting Secretary
Federal Communications Commission
1919 M Street, N.W., Room 222
Washington, D.C. 20554

Re: Ex Parte Submission
In the Matter of The Development of Operational Technical, and Spectrum Requirements for Meeting Federal, State and Local Public Safety Agency Communication Requirements Through the Year 2010
WT Docket No. 96-86

Dear Mr. Caton:

The Association for Maximum Service Television respectfully submits this late-filed report, prepared by Fox Ridge Communications, Inc., on options for meeting public safety spectrum requirements. In short, this report analyzes and builds on the recommendations of the Public Safety Wireless Advisory Committee Final Report (September 1996). The Fox Ridge report finds that, given the great fluctuation in public safety needs depending on population density, public safety needs should be met on a city-by-city basis. Increased sharing of carefully targeted slivers of the television broadcast spectrum will help meet the most immediate needs in location-sensitive ways. These first steps should precede the ultimate allocation of a full 24 MHz of television broadcast spectrum to public safety. In addition, greater spectrum efficiency by all public safety and land mobile spectrum users will reduce the need for new public safety spectrum allocations.

Please address any questions to either of the undersigned.

Sincerely yours,

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OPTIONS FOR FURTHER SHARING OF TELEVISION CHANNELS BETWEEN THE PUBLIC SAFETY COMMUNITY AND TELEVISION BROADCASTERS

Prepared for the
Association for
Maximum Service Television, Inc.
Washington, DC

March 1997

by
Fox Ridge Communications, Inc.
Arlington, Virginia 22205

OPTIONS FOR FURTHER SHARING OF TELEVISION CHANNELS BETWEEN THE PUBLIC SAFETY COMMUNITY AND TELEVISION BROADCASTERS

EXECUTIVE SUMMARY

The Public Safety Wireless Advisory Committee (PSWAC) recently submitted a report (Final Report) to the Federal Communications Commission (FCC) and the National Telecommunications and Information Administration (NTIA) which concludes that, by the year 2010, the public safety community will need overall 129.3 MHz of spectrum, of which 95.3 MHz must come from new allocations. The PSWAC derives this figure from its estimate that the public safety community of Los Angeles, California will need, by 2010, this amount of spectrum for voice, data, messaging, wide band data, and video. Based on the assumptions in the Final Report, approximately 37.8 MHz of the identified spectrum should be below 1,000 MHz. The Final Report does not, however, calculate spectrum needs for any city other than Los Angeles. The Final Report instead indicates that, if the spectrum needs can be met in Los Angeles, they can be met everywhere else.

As possible solutions to spectrum demands, the Final Report suggested that the necessary spectrum could come from a variety of sources, including additional use of television channels, federal government spectrum, and more efficient use of land mobile spectrum. At the same time, timely use of advanced, spectrum-efficient, land mobile technologies will be necessary to meet spectrum demands. The PSWAC prediction assumes a four-fold increase in the spectrum efficiency of land mobile equipment. Failure to use more efficient equipment would result in even much higher spectrum needs than those predicted by the Final Report.

This report finds that :

Concentrating on spectrum requirements below 1,000 MHz, this report analyzes the findings of the PSWAC Final Report and provides spectrum solutions using the calculated needs formula developed by the PSWAC. The analysis reveals that:

- Serious public safety needs for expanded amounts of spectrum exist only in the most highly populated markets. Spectrum needs for frequencies below 1,000 MHz are relatively low outside of these most highly populated markets.

- o The model used for the prediction of spectrum needs assumed very conservative values, resulting in prediction of enough spectrum to support extremely reliable systems designed to accommodate peak traffic loads with ease.

- o Both in today's environment and in tomorrow's world of digital television, additional opportunities exist for more sharing of spectrum between public safety radio users and television broadcasters. A city-by-city study can identify specific "sliver sharing" opportunities throughout the country.

- o Public safety spectrum users, and all land mobile users, need incentives to convert to more spectrum efficient technologies as soon as possible -- most especially in the major markets. This includes all land mobile bands (25 - 1,000 MHz). Such conversions would minimize the need for new spectrum and provide opportunities to shift spectrum between non-public safety and public safety land mobile radio users.

- o Spectrum for interoperability between agencies at all levels of government should come from government spectrum in the 380-400 MHz band.

INTRODUCTION

Public safety activities in the United States are important to everyone. Much of the success of today's modern public safety work depends on adequate wireless communications capacity. The Public Safety Wireless Advisory Committee (PSWAC), an advisory committee chartered by the Federal Communications Commission (FCC) and the National Telecommunications and Information Administration (NTIA), recently released a report projecting public safety spectrum needs through the year 2010. One of the major recommendations in the report was for public safety entities to utilize additional television spectrum.

The FCC currently has two rule making proceedings before it directly on point with the spectrum issues. The first proceeding is entitled *The Development of Operational, Technical, and Spectrum Requirements for Meeting Federal, State and Local Public Safety Requirements Through the Year 2010* (FCC Docket WT 96-86). This proceeding looks specifically at the spectrum needs of the public safety community. The second proceeding, entitled *Advanced Television Systems and Their Impact Upon the Existing Television Broadcasting Service* (FCC Docket MM 87-268), examines various issues related to advanced television systems, including spectrum requirements.

The Association for Maximum Service Television, Inc. (MSTV) requested Fox Ridge Communications, Inc. to investigate the extent to which there might be immediate options to help relieve pressures for additional public safety spectrum. This report responds to that request and focuses on spectrum needs of the public safety community below 1,000 MHz. The needs are further considered in light of the broadcast industry's conversion to advanced or digital television.

A key finding in this report is that the spectrum needs of the public safety community are highly related to population density. The needs of Los Angeles, for example, are much greater than those of Kansas City. The PSWAC found that Los Angeles needs 129.3 MHz of spectrum in 2010. Of that amount, approximately 37.8 MHz was needed below 1,000 MHz. The same formula developed by PSWAC predicts much less need in metropolitan areas of lesser population. For example, Atlanta needs only 15.84 MHz of spectrum below 1,000 MHz. By the fourth most populated area, Philadelphia, only 3.58 MHz of new spectrum will be required below 1,000 MHz in 2010. Public safety may need more spectrum during the inverveening years than in 2010, as it must migrate to more spectrally efficient equipment over this time period. Although not fully developed city-by-city in this report, it is likely that a good portion of the needed public safety spectrum can be fulfilled almost immediately by further sharing of the UHF television channels.

This report finds that the following actions should be taken to help resolve the public safety spectrum issue:

1. The Department of Defense (DoD) should be encouraged to find 2.5 MHz of spectrum in the 380.0 - 399.9 MHz band for nationwide interoperabiltiy channels.

2. Incentives should be developed to encourage the land mobile and public safety communities to convert to the most spectrally efficient equipment available as soon as possible, especially in major metropolitan areas. These incentives could include:

    a) a licensee could not access new spectrum until equipment operating in existing spectrum meets a 6.25 kHz bandwidth equivalent standard,

    b) a licensee would have to turn in existing spectrum before being licensed in new spectrum, and then licensing would be for only 6.25 kHz equivalent technology,

    c) a licensee could gain exclusivity of an existing channel if the equipment was converted to 6.25 kHz bandwidth equivalent technology,

    d) a licensee on a conventional two-way channel not utilizing trunking, TDMA, single sideband, or other efficient technology would be relicensed as a secondary user of a channel, or

    e) mandatory transition dates to convert to 6.25 kHz equivalent bandwidth equipment.

Because there is no economic incentive for conversion to more efficient technologies in the public safety services, use of the above techniques could help ensure use of new technologies as quickly as possible.

3. The FCC's Refarming channel guidelines should be applied to the 800 MHz and 900 MHz land mobile bands to create more capacity and provide the potential for reallocation from non-public safety land mobile use to public safety use. In addition, any new systems, regardless of band, should be required to meet a 6.25 kHz equivalent bandwidth standard.

4. A city-by-city study should be conducted to determine the extent of further sharing of television spectrum that may be possible in the near term.

BACKGROUND

The Public Safety Community. The public safety community has the responsibility to protect the safety and life of every citizen in the country. More and more the success of public safety operations rely on the use of new electronic technology and communications. Expanded computing power, wide area data networks, and electronic surveillance have become necessary parts of public safety operations. The need for such services now extends directly to the patrol car, the fire engine, the ambulance, and the patrolman walking a beat.

Extending the modern tools of the trade to the mobile environment has begun to make demands on the electromagnetic spectrum that cannot easily be satisfied. All levels of government need and want new wireless services. Agencies at all levels of government also have a need to communicate with each other more than ever before. The Oklahoma bombing incident stands out as a prime example of how communications have become pivotal in the performance of modern law enforcement.

Current Land Mobile Spectrum. The public safety community uses land mobile frequencies spread over many bands, generally below 1,000 megahertz. The primary frequency bands currently used are:

VHF Low Band	25 - 50 MHz	non-federal use
	30 - 50 MHz	federal use

Generally used for longer range, single channel (simplex) communications typical of highway patrol and similar activities. Equipment availability is becoming a problem in these bands.

VHF High Band	150 - 174 MHz	non-federal use
	162 - 174 MHz	federal use

Widely used for single channel (simplex) and two-channel (half duplex) dispatch communications.

220 MHz	220 - 222 MHz	non-federal and federal use (by channel)

Not used due to lack of equipment and regulatory delays. The band will more likely be used by commercial communications entities through the FCC auctioning process.

UHF Low Band	450 - 470 MHz	non-federal use	
"T Band"	470 - 512 MHz	non-federal use	
	406 - 420 MHz	federal use	

Widely used for dispatch in the half duplex mode (two channels used with messages being repeated from one frequency to the other by fixed equipment to extend mobile-to-mobile range).

UHF High Band	806 - 821 MHz	non-federal use	(800 MHz Band)
	821 - 824 MHz	non-federal public safety use	
	851 - 866 MHz	non-federal use	
	866 - 869 MHz	non-federal public safety use	

Same as 400 MHz bands.

The non-federal public safety community shares the listed bands with other land mobile users, so the total spectrum devoted to public safety is somewhat less than shown above. The present public safety allocation is actually about 23.2 MHz spread among the non-federal bands shown above.[1]

The Regulatory Environment. The responsibility for spectrum management rests with two organizations within the federal government. The FCC regulates the use of spectrum for non-federal uses, including public safety radio use for state and local agencies. The NTIA, part of the Department of Commerce, controls federal government use of the spectrum. In some cases, both agencies may have joint control over shared segments of spectrum.

Over the years, the FCC and NTIA have had a number of initiatives to provide for public safety spectrum needs. Some of those initiatives have been instituted at the request of Congress, while others have been agency-sponsored proceedings. One of the most significant initiatives was the reallocation of six megahertz of spectrum in the 800 MHz band for non-federal public safety use in the mid-1980's. This reallocation occurred in response to a Congressional mandate in 1983 that required the FCC to provide for public safety spectrum needs through the year 2000. The FCC also set up an advisory committee (the National Public Safety Planning Advisory Committee (NPSPAC)) to help it decide how to license the spectrum.

The NPSPAC recommended a unique method of assigning channels in the new six megahertz band by setting up regional planning committees, each empowered to

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[1] *See* PSWAC Final Report § 1.28.

determine the local needs of the areas and then forward corresponding regional licensing plans to the FCC. In this way, each of the 55 FCC-defined regions met their individual needs in ways that made sense within each region. This approach was an attempt to eliminate the inefficiencies associated with making a national plan fit local needs. All 55 regions have a plan in place.

In 1988, as the regional plans were being finished, the Commission initiated a rule making proceeding to examine the options for public safety agencies to have interoperable equipment at 800 MHz.[2] This proceeding remains open, but a decision has been delayed due to more recent regulatory developments. Nevertheless, this docket highlights the need for interoperability among public safety agencies, particularly in times of disaster.

In addition, both the FCC and NTIA have attempted to encourage better spectrum efficiency through channel splitting in the land mobile bands below 512 MHz. These bands are typically used for voice and data dispatch type operations. Most equipment now operates at bandwidths of 25.0 kHz. Both agencies have, however, adopted plans to split existing channels by two, potentially doubling the capacity of some land mobile bands. The FCC has further adopted a second channel split for the year 2005, making a potential four times increase in capacity.[3] Although the NTIA adopted a specific cut-over date for federal agencies to convert to 12.5 kHz technology, the FCC has not adopted mandatory cut-over dates.

The FCC has set dates after which new equipment (not previously approved by the FCC as being acceptable for licensing) must meet new bandwidth/efficiency standards. The idea is that manufacturers will begin producing more efficient equipment after the critical dates. Then, as licensees change out equipment in the normal replacement cycle, they will eventually convert to more efficient technologies, as the older wide band equipment will no longer be available. In addition, the FCC is not specifically requiring the use of narrow band equipment. (The Commission will also certify new equipment designs of up to 25.0 kHz bandwidth as long as it can pass two times, and later four times, the traffic of a traditional analog FM 25.0 kHz radio. This is referred to as "equivalent efficiency." Efficiency measurement standards are provided for in the FCC rules.)

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[2] *See generally*, FCC Docket 88-441, Technical compatibility protocol standards for equipment operating in the 800 MHz public safety bands.

[3] *See generally*, FCC Docket 92-235, Replacement of Part 90 by Part 88 to Revise the Private Land Mobile Radio Services and Modify the Policies Governing Them.

Somewhat concurrently with the proceedings at the FCC and NTIA to improve spectrum efficiency in the land mobile bands, Congress became aware of the growing needs of the public safety community. In 1993, Congress directed the FCC to conduct a study of public safety spectrum needs through the year 2010 and to develop a plan to meet those needs. The FCC released the results of its study in February 1995, but concluded that it did not have enough information to make a determination regarding public safety needs and that more study would be necessary. In an attempt to gain the necessary information, the FCC and NTIA established the Public Safety Wireless Advisory Committee and subsequently opened a new rule making proceeding relating to overall communication needs of public safety.[4]

The Public Safety Wireless Advisory Committee. In order to involve the experts in the field in the process, the FCC and NTIA established the PSWAC on June 25, 1995. The PSWAC was chartered to:

- Advise the FCC and NTIA of specific operational wireless needs of the community including improvement of basic voice, data, and E911 services, and the implementation of new wide-area, broadband telecommunications technologies for transmission of mug shots, fingerprints, video, and other high-speed data.

- Advise the NTIA and FCC on options to provide for greater interoperability among federal, state, and local Public Safety entities.

- Advise the FCC and NTIA on options to accommodate growth of basic and emerging services, including bandwidth vs. functional requirements trade-offs, technical options, and other options.

- Advise the NTIA and FCC on the total spectrum requirements for the operational needs referred to above, including frequency band options, shared/joint spectrum use options, and other options.

PSWAC Structure. The advisory committee structure consisted of a chairman, a Steering Committee, five subcommittees, working groups, and participants. Philip L. Verveer, partner in the law firm of Wilkie Farr & Gallagher, chaired the committee. Steering Committee members included representatives from police and fire organizations, other public safety and public service organizations, manufacturers,

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[4] *See Generally,* FCC Docket WT 96-86, The Development of Operational, Technical, and Spectrum Requirements for Meeting Federal, State and Local Public Safety Communication Requirements Through the Year 2010.

federal government agencies and the Department of Defense.[5]

The Steering Committee served as the Board of Directors for the PSWAC. One of the Steering Committee's primary tasks was to review the work of the various subcommittees for fairness and accuracy. The Steering Committee also had the responsibility to review and approve the final report of the PSWAC.

The five subcommittees were charged with developing the necessary data and reports to respond to the charter questions. The five subcommittees were as follows:

> *Operational Requirements Subcommittee (ORSC)*, chaired by Mr. Paul Wieck, Commissioner, Iowa Department of Public Safety. This Subcommittee identified the operational needs of the public safety community through the year 2010, without regard to spectrum requirements.
>
> *Technical Subcommittee (TESC)*, chaired by Mr. Alfred Mello, Chairman, Public Safety Communications Council. This Subcommittee matched operational requirements with technology, including expected spectrum efficiency improvements. The Subcommittee also identified general frequency bands that would support the desired operational capability.
>
> *Interoperability Subcommittee (ISC)*, chaired by Mr. James Downes of the U.S. Department of Treasury. This Subcommittee considered how agencies at all levels of government could communicate, particularly in times of disaster.
>
> *Spectrum Requirements Subcommittee (SRSC)*, chaired by Mr. Richard Allen of the FBI. This Subcommittee compared the spectrum requirements of the Technical Subcommittee to potential allocations in the spectrum. It additionally considered how spectrum could be used to meet the interoperability needs identified by the Interoperability Subcommittee.

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[5] The members of the Steering Committee were: the Honorable Louis Freeh, Director, FBI; the Honorable Howard Safir, Police Commissioner, New York City; the Honorable Michael Freeman, Fire Chief, Los Angeles County; the Honorable Alan Bersin, US Attorney for the Southern District of California; Mr. Raymond Kelly, Undersecretary for Enforcement, Treasury Department; Mr. Harlin McEwen, Deputy Assistant Director, FBI and senior representative from the International Association of Chiefs of Police; Ms. Cindy Raiford, Deputy Director of Communications, DoD; Mr. Steven Proctor, Technical Manager for Communications, State of Utah and past president of the Association of Public Safety Communications Officials International, Inc.; Mr. Dennis Connors, Vice President, Ericsson, Inc.; and Mr. Fred Kuznik, Vice President, Motorola, Inc.

Transition Subcommittee (TRSC), chaired by Mr. James Rand, Executive Director, Association of Public Safety Communications Officials, International, Inc. This subcommittee examined ways to provide for a smooth transition to the new technologies, including funding options.

Several meetings of the subcommittees and Steering Committee were held over a one year period. The PSWAC's Final Report was delivered to the FCC and the NTIA in September 1996.[6]

PSWAC Final Report Findings. The final report of the PSWAC consisted of an overview section followed by the individual subcommittee reports. The final report suggested several options to achieve the needed capacity for the public safety community, including more use of shared trunked systems between agencies, use of commercial services, mandatory cut over dates for more efficient equipment, and reallocation of spectrum. Having taken all of the options into account, the PSWAC found that 129.3 MHz of spectrum will be required overall by the year 2010, with 95.3 MHz of that spectrum being from new allocations.

In addition, the report recommended 161 MHz of new point-to-point (microwave) spectrum and 2.5 MHz of nationwide land mobile spectrum to support interoperabilty needs between all agencies. All of this new spectrum, except for the interoperability band/channels, would be for non-federal needs, as the report concluded that the federal government could satisfy its requirements in existing spectrum.[7]

Although the reports of all five subcommittees entered into the final spectrum decisions of the PSWAC, the work of the SRSC is essentially the culmination of the work of the others. The work of the other four subcommittees will be analyzed to some extent, but primary attention will be given to the methodology used by the SRSC. The SRSC matched the identified operational requirements of the Operational Requirements and Interoperability Subcommittees with the technical options presented by the Technology Subcommittee. These data were then applied to a spectrum prediction model in order to determine the final spectrum requirements. Finally, the SRSC examined existing spectrum allocations to consider how spectrum might be reallocated to meet the

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[6] *See* Final Report of the Public Safety Wireless Advisory Committee, Volumes I and II, September 11, 1996.

[7] The report indicated that no new federal spectrum will be required as long as 1) no additional spectrum is reallocated for commercial uses, 2) spectrum efficient technologies become available, and 3) funds are provided to allow the new technologies to be implemented. *See* Final Report of the Public Safety Wireless Advisory Committee, Volume I, § 4.4.9.

identified needs.

In no case was unincumbered spectrum identified. The PSWAC found the UHF television spectrum as being particularly attractive for much of the new spectrum it needs. The remainder of this report explores the methodology of the spectrum prediction model and alternatives that may help to meet the spectrum needs.

ANALYSIS OF PSWAC SPECTRUM REQUIREMENTS

As with any report or suggestion, one can take exception with some of the assumptions made by the PSWAC. The question is whether the assumptions are reasonable even if not entirely accurate. This report concentrates on the spectrum requirements below 1,000 MHz, as they are likely to be the most difficult to satisfy. Specific requirements for wide band data and video that the PSWAC identified for above 1,000 MHz are not addressed.

Operational Requirements. The approach of the Operational Requirements Subcommittee was to examine each type of end user entity and analyze what the wireless communications needs are or will be. Although many types of potential communications capabilities were examined, the subcommittee found that voice dispatch and data exchange were the primary communication needs that must be satisfied. For example, the Subcommittee identified some limited instances in which real time video might be desired, but that requirement certainly does not compare to the day-to-day voice and data requirements. The Intelligent Transportation System was also explored and found to create some legitimate needs for future spectrum capacity.

Generally, the types of operational needs identified by the Operational Requirements Subcommittee seem reasonable, although some types of services may not be implemented due to funding restrictions on public safety agencies. The Subcommittee correctly identified that the need to transport data to mobile units will become increasingly critical to the success of future public safety operations. Data provides an abundance of on-scene information in a very spectrally efficient manner.

Technology. The Technology Subcommittee conducted an exhaustive analysis of technologies that can be employed to meet the operational requirements that were identified. In addition to technologies that require dedicated public safety spectrum, commercial alternatives were explored. Cellular, Personal Communications Systems, satellites, and Specialized Mobile Radio Systems were considered as alternatives to individually constructed systems.

Key to understanding the spectrum requirements identified by the PSWAC is the assumption of improvements in the spectrum efficiency of equipment over time. The subcommittee expects a 2:1 improvement over 25 kHz FM in the next five years and a 4:1 improvement by 2010. The subcommittee anticipated that an 8:1 improvement could be possible within 15 years, but declined to use that level of improvement in its calculations. The subcommittee also recognized that advanced technologies such as Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA), Single Sideband (SSB), and Time Division Duplexing (TDD) could provide more opportunities for shared systems between different agencies.

The Subcommittee also projected improvement in silicon and other technologies over the next several years. For example, the subcommittee projected clock rates of over 1,000 MHz by the year 2010. As communications equipment and computer technology continue to merge, the enhanced data rates mean more flexibility and throughput for a given bandwidth. Overall the Subcommittee's assumptions for improved compression and technology advancements appear reasonable.

Interoperability. One of the most difficult issues to be addressed was that of the ability of different agencies to communicate with each other as necessary (interoperability). The problem is complex for several reasons. First, as previously noted, public safety agencies operate on numerous different frequencies. Although equipment may operate over a complete band (e.g. 150-174 MHz), it has not traditionally operated in multiple bands. Thus, for a fire department operating on 40 MHz to talk to a police department operating on 155 MHz, two radios have to be installed in every location and vehicle that require the capability. Although the FCC, as part of the NPSPAC recommendations, attempted to relieve the interoperability problem by allocating several 800 MHz channels for interoperability, the multiple band allocations have limited the success of the effort. Only agencies operating in the 800 MHz band have been able to take advantage of the channels.

Second, advances in technologies have brought multiple types of equipment to the market place. Most of the technologies referred to in the previous section will not operate together even if on the same channels. Thus, either a single transmission mode must be chosen for all equipment or "gateway" devices must be installed to convert technologies to make them compatible.[8]

The Interoperability Subcommittee recommended an approach of creating additional interoperability channels in or adjacent to each existing band and establishing a new

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[8] Gateway devices are fixed infrastructure that essentially take in one type of technology and transmit out a different technology, repeating the incoming message content.

interoperability band (referred to as the PI Band). The recommendation calls for 21 repeated voice links and 20 simplex voice links within existing bands. In the new band, the report calls for 31 repeated voice channels, 70 simplex voice channels, two high speed data channels, and two full motion video channels. The minimum baseline technology for the interoperabilty channels was recommended as 16K0F3E (25 kHz analog FM voice). The Subcommittee recommended that, effective January 1, 2005, the baseline technology be reduced to 12.5 kHz analog FM voice.[9] The Subcommittee further recommended that the spectrum for the PI band be below 512 MHz.[10]

These recommendations seem reasonable for metropolitan areas. For smaller markets, the suggested interoperability needs would likely be less. However, because one cannot anticipate which agencies will need to work together and when, the concept of nationwide common assignments has considerable merit.

Spectrum Requirements. Based on the requirements identified above, the Spectrum Requirements Subcommittee determined the spectrum requirements for Los Angeles shown below.

Service	Spectrum (MHz)
Voice	32.3
Data	5.3
Status/Message	0.2
Wide Band Data	40.8
Video	50.7
Subtotal	129.3
Present Allocation	-23.2
Loss of 25 - 50 MHz	-6.3
Existing TV Sharing	6.5
Commercial Servs.	-10.6
Net Need in 2010	95.3

The Subcommittee utilized a model developed by Motorola, Inc. and refined by Working Group 8 of the Subcommittee.[11] Los Angeles was chosen as a high population area for the model on the assumption that if the needs in Los Angeles could be met, they could be met in the rest of the nation as well. The specific public safety

[9] *See* PSWAC Final Report, Appendix C, § 11.2.4.

[10] *See* PSWAC Final Report, Appendix C, § 11.2.2.

[11] *See* PSWAC Final Report, Appendix D, page 607.

demographics for the model were taken from the New York metropolitan area.[12] The Final Report suggests that almost all of the wide band data and video allocations will be above 1,000 MHz.[13] This immediately eliminates 91.5 MHz (40.8 + 50.7) of spectrum below 1,000 MHz as a requirement. This leaves a maximum potential of 37.8 MHz below 1,000 MHz for voice, data, and messaging.

The current allocation is 23.2 MHz, so the maximum new spectrum below 1,000 MHz would be 14.6 MHz (37.8 - 23.2). The Final Report does make the point that no new equipment is being manufactured for the 25-50 MHz band. Public safety has 6.3 MHz of spectrum in that band. Assuming loss of that band because of lack of equipment, the total spectrum requirement could go as high as 14.6 + 6.3 = 20.9 MHz in the Los Angeles, except that Los Angeles gains some of that capacity back through existing sharing of television spectrum.[14] However, as discussed further below, inteoperabilty and other considerations must be taken into account. Also, policy decisions for common, nationwide public safety bands could result in more new spectrum allocations, but with a corresponding return of spectrum now being used by public safety.

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[12] *See* PSWAC Final Report, Appendix D, page 607.

[13] *See* PSWAC Final Report, Appendix D. The Final Report suggests use of 1710 - 1755 MHz at paragraphs 10.2.7.1 and 11.2.2 and use of 1990 - 2110 MHz at paragraph 10.2.6.

[14] The Final Report uses 23.4 MHz in its calculations for existing spectrum in the model rather than 23.2 MHz. This is because the Final Report assumes loss of use of the 6.3 MHz of spectrum in the 25 - 50 MHz band due to lack of available equipment and non-desirable propagation characteristics for new and enhanced systems. The Final Report then adds back in the use of television channels in the 14 - 20 band in Los Angeles (6.5 MHz). Thus, for Los Angeles, which has use of an extra television channel (16), the existing spectrum is taken to be 23.4 MHz (23.2 - 6.3 + 6.5). Similar corrections for loss of the 25 - 50 MHz and existing sharing of television channels 14 - 20 would be required for each major market. However, the assumption of 6.5 MHz does not correspond to the allocations in the FCC rules. Section 90.309 shows almost 2.0 MHz allocated from channel 14 television and another 2.0 MHz from television channel 20. Even dividing the available spectrum by two, as the two-way channels are paired, Los Angeles would have 6.0 + 2.0 = 8.0 MHz. The 8.0 MHz also assumes that no public safety entities are licensed in the General Access Pool. Calculations found Appendix A of this report generally use the spectrum sharing values in Section 90.309 rounded to the nearest half megahertz. Los Angeles and New York are, however, additionally unique in that they both have a 6.0 MHz television channel devoted entirely to public safety in addition to general sharing of television channels 14 - 20. *See* PSWAC Final Report § 9.3.1.6.

The Prediction Model. The Motorola model, as modified by the Working Group 8, is quite complex and makes use of numerous variables. Most of those variables do not have exact values, but must be themselves predicted based on some knowledge of the environment. Thus, the accuracy of the prediction is only as accurate as the assumptions that went into the prediction.

The basic equation for the model is:[15]

$$\text{MHz} = \frac{10000*\text{ERL}*\text{POP}*\text{PEN}*\text{SRC}}{\text{COD}*\text{RATE}*\text{LOAD}*\text{REUS}*(100-\text{ERR})}$$

where,

COD = dimensionless factor for coding improvements between now and 2010 (1.0 or greater)
ERL = traffic patterns for public safety users expressed in Erlangs
ERR = dimensionless error coding and overhead (taken as 50 per cent)
LOAD = dimensionless percentage of time a channel is loaded (in use)
MHz = Megahertz of calculated needed spectrum
PEN = dimensionless percentage of penetration of communications devices into public safety population
POP = population of public safety users
RATE = transmission rate (bits/second/Hz)
REUS = dimensionless channel geographic reuse factor (1.0 represents no reuse in an area)
SRC = data rate of source data being transmitted (6 bits/second)

The validity of each of the variables actually used by the PSWAC will be considered separately.

10000. This is a dimensionless factor "K" never defined in the Final Report. The most information about it is that it is a normalization factor used to "accommodate the units and the type of service being analyzed."[16]

COD. The Final Report assumes that coding improvement will double for voice

[15] *See* PSWAC Final Report, Appendix D, page 633.

[16] *See* PSWAC Final Report, Appendix D, page 664.

and messaging, but remain unchanged for data. These factors at first seem conservative. Data compression techniques are advancing rapidly; however, the mobile environment is very harsh due to multipath and fading. Use of heavy compression in the mobile environment may not be possible. The chosen factors seem reasonable for this case.

ERL. Erlangs (channel occupancy) requirements. See discussion for "LOAD" below.

ERR. Error correcting code and overhead traffic were set at 50 per cent for all types of transmissions. The figure seems conservative. A 50 per cent figure suggests that for every bit of data that passes through the transmission path, it takes an additional bit of data to make it happen. Use of such a figure *doubles* the spectrum projection, a considerable price to be paid. In a mobile environment with fading and multipath, the figure may represent a realistic planning factor, but one would hope for something better by 2010.

LOAD. A factor of 54.5 per cent was used for channel loading for all types of modulation. Blocking time, queuing time, and duration of each exchange of transmissions enter into the maximum loading that a channel can accept. The Final Report indicates that the chosen figure was based on a White Paper submitted by the Immigration and Naturalization Service.[17] Although the final calculation is never shown in the paper, it is based on a 20 channel trunked system (19 working channels and one control channel) with a blocking of one per cent (one call in 100 would not go through immediately during a busy hour). It also assumes a traffic load of 0.027354 Erlangs per officer per busy hour (226 seconds of air time every hour per user). A 20 channel trunked system would thus support only 165 users in busy hours. The FCC rules would currently require such a system to support 2000 users to be considered fully loaded. At 2000 users and one per cent blocking, the system could give each user 18.7 seconds of air time per hour.[18] This is particularly interesting, as the PSWAC Final Report on page 660 suggests that the average message length for a voice message is only 24 seconds, not 226 seconds. Suggesting that a twenty channel trunked system can support only 165 users is unrealistic.

The first question is whether a one per cent blocking rate is truly required in the busiest time of the day, giving rise to basically no blockage during off-peak time.

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[17] *See* PSWAC Final Report, Appendix D, pages 632 and 668-683.

[18] *See* PSWAC Final Report, Appendix D, page 681.

The second question relates to the assumption made to calculate peak time Erlangs. The assumption was made that the number of officers wanting a channel would remain unchanged from off-peak times, but each would want four times the amount of air time. This is probably not the case. In fact, busy hours are more likely caused by more officers wanting to make fairly short transmissions. Thus, the blockage or time in queue would be considerably different than if all exchanges were truly 226 seconds in length.

Simplistically looking at this difference in approach, if the peak rate was caused by four times the officers wanting to talk rather than each officer wanting to talk four times as long, the maximum wait time would be 226/4=56.5 seconds for a channel assuming all channels (trunks) were blocked concurrently (all conversations started and would end at the same time on all trunks). In fact trunks open up randomly so one could hardly anticipate any wait. Again simplistically looking at the effect of trunking, one can simply divide the potential single channel wait time by the number of trunks and find a potential maximum wait of 56.5/19=2.97 seconds (one of the twenty channels is assumed lost to a control channel). Although one might argue with this simplistic model, it illustrates that the nature of the traffic plays an important role in the calculation.

Although the methodology of determining the load factor may not hold for a 20 channel trunked system, it may be reasonable for the general type of public safety system. Many systems will remain just one channel or at most a handful of trunked channels. Even so, the figure should probably be higher by some amount, but it can be used as an acceptable value for planning <u>very reliable</u> communications systems. Adequate communications could reasonably accept loading well in excess of 54.5 per cent.

PEN. The penetration rates were based on actual data and are assumed to be correct for New York. Whether they hold in other cities would require additional study. The penetration figure also does not appear to take into account that not all officers work all the time. Because there would likely be two or three shifts each day, the PEN (or POP) should probably be reduced accordingly by a factor of two or three. For planning purposes the penetration figures seem reasonable for disaster restoration periods, but may contribute to a calculation of much more spectrum than needed for non-disaster situations. The figure can be used for worst-case calculations.

POP. The Final Report relies on the population figures for Los Angeles. While that logic makes sense, it begs the question of what the spectrum demands are in other parts of the country. For example, the Final Report indicates that the Rand

McNally projects that the Los Angeles area will have slightly under 14.5 million residents by 2010. Metropolitan areas, except for New York, quickly fall from that figure. Most of the top ten metropolitan areas are predicted to have populations around five million. By the twentieth market, the population is down to around two million.

In the model, population is a key factor in predicting spectrum need. It is a direct factor in the numerator of the equation. All other factors being equal, the equation would predict that the spectrum need is less than 37.8 MHz for voice, data, and messaging in all areas of the country except for New York and Los Angeles. Using a direct population substitution for the Los Angeles population (14,455,675) in the equation, one finds that metropolitan areas with populations of less than 6,462,986 residents will require no new spectrum for voice, data, and messaging. At that level, the formula predicts the need for only 16.9 MHz or the current allocation of 23.2 MHz minus the loss of 6.3 MHz in the 25 - 50 MHz band.

Even at the above-calculated level, there remains the need for some new spectrum. One of the major goals of the PSWAC work was to provide nationwide interoperability for all levels of agencies, including the federal government. The recommendation in the Final Report is for 2.5 MHz to be allocated nationwide for interoperability. This band must be a common nationwide band, not just random allocations of bandwidths in each community. Therefore, throughout the country there is a need for a new band of at least 2.5 MHz. The Final Report suggests that this spectrum be between 138 MHz and 512 MHz.[19]

There may also be some good policy reasons to allocate additional spectrum for public safety. For example, minimizing the number of bands in use makes interoperability much easier, as a single radio can cover the working and interoperability channels. In addition, some wide band data and video could be considered below 1,000 MHz. Assuming one channel of compressed video or data on a nationwide basis, an allocation of 3 MHz would seem reasonable. Using these assumptions, a nationwide requirement of 5.5 MHz of new spectrum would exist for interoperability, video, and wide band data, regardless of existing allocations.

RATE. The prediction model consistently uses 1.5 bits/second/hertz for voice, data, and messaging. The model uses 3.5 b/s/Hz for wide band data and video.

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[19] *See* PSWAC Final Report, § 2.2.1.

The value is consistent with use of a 4.0 kHz bandwidth per channel, assuming a 6.0 kb/s data rate.

REUS. The Final Report assumed a frequency reuse pattern of 2.5 in an area. Unless more advanced technologies similar to cellular or enhanced SMR are used, 2.5 seems reasonable. Because of the need and desire to cover large areas with dispatch signals, it makes more sense to use single sites that cover large geographic areas rather than small sites that serve only limited areas. In other words, if the dispatch calls would bring up essentially all transmitters in a cellular type configuration, then nothing is gained by that configuration. The assumption is reasonable.

SRC. A constant assumption of 6 kilobits per second is assumed in the Final Report for voice, data, and messaging, or the below 1,000 MHz services. The value seems low; however, in the mobile environment it may be reasonable. It is difficult to imagine that such a low data rate will actually be acceptable in three years, let alone 15 years. For conservative planning purposes it is reasonable.

Summary of Observations. The majority of the planning factors for the spectrum modeling equation appear reasonable, but conservative. Taken together, the factors suggest peculiar outcomes. For example, the suggested 1.5 b/s/Hz taken with a 50 per cent overhead factor gives an effective throughput of only 0.75 b/s/Hz. Less than an effective rate of 1.0 b/s/Hz appears quite conservative. Additionally a channel loading factor of only 54.5 per cent in peak hours seems extremely low. Neither the penetration or population figures take into account shifts, so the anticipated number of officers using communications equipment may be high by as much as a factor of three. Also, as stated above, the assumption that each officer needs four times the air time in peak periods is likely flawed, as more likely more officers would need air time in peak periods for about the same length of time as in off-peak periods.

GEOGRAPHIC SPECTRUM REQUIREMENTS OVER TIME

Taking the varying populations of the top 20 markets into account, the first table in Appendix A projects spectrum needs in 2010 for those markets (page A.1). As can be seen, by the year 2010, only New York, Los Angeles, and Chicago will have new spectrum needs that must be satisfied by new spectrum. Beginning with Philadelphia, only the 5.5 MHz for interoperability and video/data below 1,000 MHz will be required, and then only to make spectrum congruent across the country.

What is missing from the PSWAC work and from the above analysis is an analysis of spectrum needs, city-by-city and year-by-year, from now till 2010. The projections in the Final Report for 2010 assume highly efficient technology in use by all public safety agencies. That equipment for the most part must yet be developed. In the interim, new needs will arise that must be fulfilled by 25.0 kHz and 12.5 kHz equipment. Therefore, the public safety community many have a greater spectrum need in five years than in 15 years. The next series of tables in Appendix A of this report take the PSWAC assumptions and spectrum formula and analyze trends over both geography and time.

Appendix A is a straight forward extrapolation of the data from the PSWAC Final Report. The first step was to take the Los Angeles prediction of 37.8 MHz and determine how population variation throughout the country would affect spectrum demand using the PSWAC formula. The figures shown for 2010 are merely the Los Angeles prediction multiplied by the ratios of populations in various cities to the population in Los Angeles (see page A.1).[20]

The next step in Appendix A takes the various factors that are used in the PSWAC prediction model equation and varies them with time. For example, the RATE in 2010 is assumed to be 1.5 b/s/Hz. For planning purposes, today's rate was taken to be 0.77 b/s/Hz.[21] Figures for 2000 and 2005 are straight line interpolations of these two limits. Similarly, the ERR is varied from 55 to 50, as assumed in the PSWAC Final Report. SRC is assumed to be only 4.8 kb/s (the FCC standard from its Refarming docket) today and goes to the PSWAC assumed rate of 6 kb/s in 2010. COD remains at 1.0 for data and goes from 1.0 to 2.0 for voice and messaging, again as assumed in the PSWAC Final Report. ERL is interpolated between today's value and the projected value in 2010. Finally, population figures come directly from the PSWAC population table in its Appendix D.[22]

All of the values are then normalized to year 2010 figures and calculated in the following equation to get a yearly multiplier of spectrum need change with the above variations. This approach thus takes into account increased traffic demand and

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[20] The contribution for current sharing of television channels 14 - 20 was taken to be the allocated spectrum for public safety per television channel assigned to the market as shown in Section 90.309 of the FCC rules rounded to the nearest half megahertz. In the cases of Los Angeles and New York, an additional six megahertz was added because of the special sharing assignments of an entire television channel assigned to public safety (this is consistent with the assumption made by the PSWAC).

[21] *See* The PSWAC Final Report indicates that non-linear, constant envelope systems have approached 1.28 b/s/Hz. For conservative planning purposes, today's rate was taken as 0.77 b/s/Hz (9600 baud in 12.5 KHz). *See* PSWAC Final Report, § 4.2.25.

[22] *See* PSWAC Final Report, Appendix D, pages 646-648.

improvements in technology to arrive at spectrum demand over time. Variables were assumed to vary equally for voice, data, and messaging, except that the COD for data was retained at 1.0 rather than 2.0 for voice and messaging. The normalized values used in the following equation to calculate the yearly factor "F."

$$F = \frac{(ERL)(POP)(SRC)}{(COD)(RATE)(ERR)}$$

Page A.2 of Appendix A shows the results of the factor calculation and its effect on yearly demand in Los Angeles. The next pages in the Appendix apply the new yearly demand for Los Angeles to other cities for the years 1997, 2000, and 2005 (pages A.3, A.4, and A.5)[23]. The next chart of the Appendix list the demands by city and year (page A .6). The last chart backs out the 2.5 MHz for interoperability for reasons to be discussed in the following sections (page A.7).

The analysis in Appendix A (page A.7) shows that the greatest need for public safety spectrum is now. By 2010, only three cities (New York, Los Angeles and Chicago) will require more than 6.0 MHz of new spectrum.

There are two factors, however, that could alter this projection. First, the public safety community has few, if any, incentives at this time to move to the more efficient technologies assumed by the PSWAC. If old technologies continue to be used indefinitely, the demand for spectrum will increase from today forward as the demand for traffic increases. The importance of changing to new technologies in a timely manner cannot be overstated. For example, in Los Angeles, if the traffic load increases as predicted but existing technology parameters are considered, the spectrum demand below 1,000 MHz would be 121.7 MHz.[24] This is quite a discrepancy from the 37.8 MHz from the PSWAC projections. Similar projections would apply for other cities as well.

Second, policy makers may determine that it is desirable to allocate more spectrum to public safety operations in order to bring most operations into a common band. If this turns out to be the case, many of the existing allocations would be vacated in favor of some nationwide contiguous spectrum. For purposes of further analysis in this report,

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[23]Note that the population ratios between cities were taken as the 2010 ratios for all years for ease of calculation. Additionally, the only other population data in the PSWAC Final Report was for 1990, not 1996 or 1997.

[24] This figure applies all of the assumed parameters of today's equipment to the Erlang load and population anticipated for 2010.

it is assumed that the public safety community will change out equipment and that there will be no migration to a common, nationwide band, except for the interoperability channels.

ANALYSIS OF SPECTRUM OPTIONS IDENTIFIED BY THE PSWAC

Voice, Data, Messaging, and Video Requirements. The PSWAC Final Report identified eight options for meeting spectrum needs below 1,000 MHz.[25] The options are as follows:

1. Immediate further sharing of TV channels in the 470 - 512 MHz band in all areas.
2. Reallocate all or part of 746 - 806 (broadcast channels 60 - 69) MHz band.
3. Immediate allocation of the VHF and UHF channels in other services created by the FCC's Refarming Proceeding (including TV sharing bands).
4. Eventual reallocation of all TV sharing channels in the 470 - 512 MHz band.
5. Immediate new sharing of the 174 - 216 MHz VHF TV band primarily outside of urban areas and for statewide systems.
6. Reallocation of the 380 - 399.9 MHz band.
7. Sharing of the 380 - 399.9 MHz band with DOD on a mutually agreeable basis to minimize interference to public safety operations.
8. Hold a portion of the 174 - 216 MHz band in reserve to meet future public safety needs, or needs not met by this effort.

Five of the options involve additional use of television broadcast channels, two options suggest use of Department of Defense (DoD) frequencies, and one option reallocates existing land mobile spectrum from non-public safety use to public safety use. The following is an analysis of various spectrum options to satisfy public safety needs.

Interoperability Frequencies. The first consideration for new spectrum should relate to interoperability. While spectrum shortages for any specific agency can be critical to operations, the inability of different agencies to communicate can be detrimental to entire communities or the country. Particularly in times of disaster recovery, it is critical that all affected agencies have the ability to communicate with each other. There is almost no opportunity for this to occur today. The PSWAC Final Report called for 2.5 MHz of new spectrum to be dedicated to interoperability and suggested that the spectrum be below 512 MHz.[26]

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[25] *See* PSWAC Final Report, § 4.4.16.

[26] *See* PSWAC Final Report, §§ 4.3.27.1 and 4.4.1.